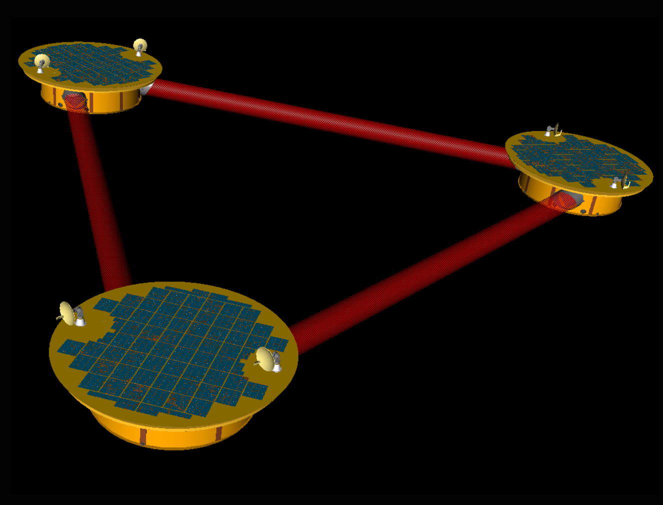
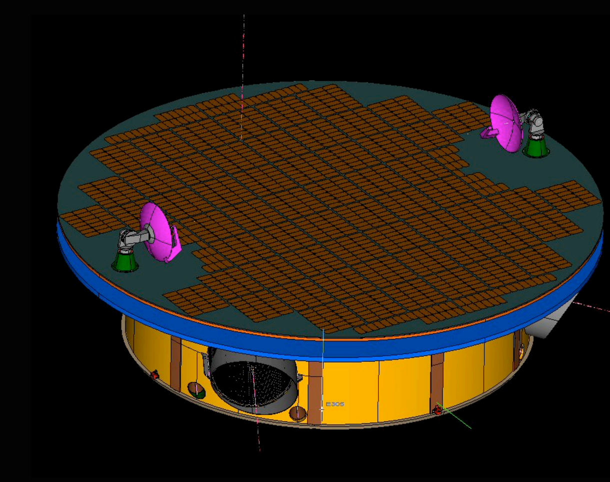
LISA Mission Architecture





Nicholas M. Jedrich, Robin T. Stebbins, Jeffrey C. Livas, Stephen M. Merkowitz
NASA Goddard Space Flight Center, Greenbelt MD 20771, USA

Abstract. The Laser Interferometer Space Antenna (LISA) mission is a unique mission design in that three spacecraft and their associated operations form one distributed science instrument, unlike more conventional missions where one or more science instruments are components of an individual spacecraft. The interferometer measurements between spacecraft that form the basis for the science measurements, i.e. strain, rely on all three of the spacecraft interacting as designed. The performance of one spacecraft in the LISA constellation is directly coupled to the performance of the two remaining spacecraft in order for the instrument to collect meaningful science data. This dependency on all three spacecraft to function as the instrument is the primary driver for unique design requirements that span all spacecraft subsystems and the overall mission design. A detailed discussion will be presented that describes the spacecraft and current mission architecture needed to meet the LISA science requirements.

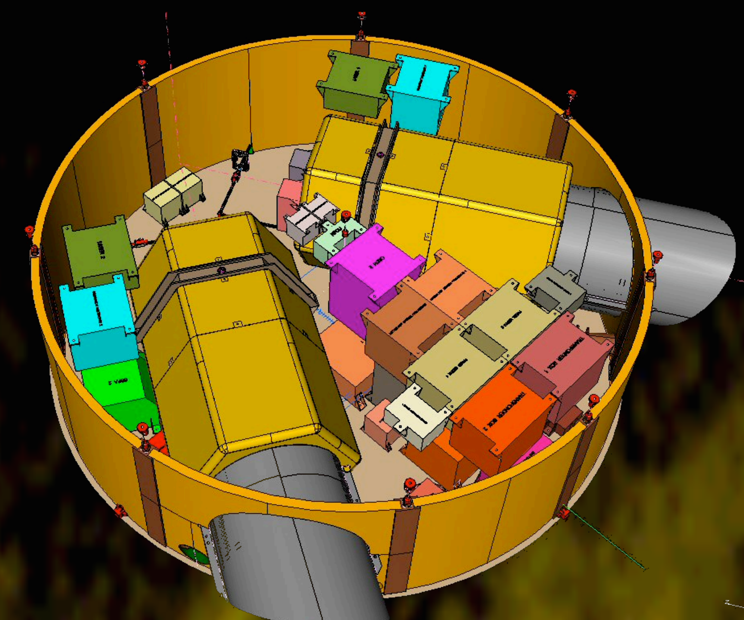
3 Sciencecraft ➡ 1 Instrument

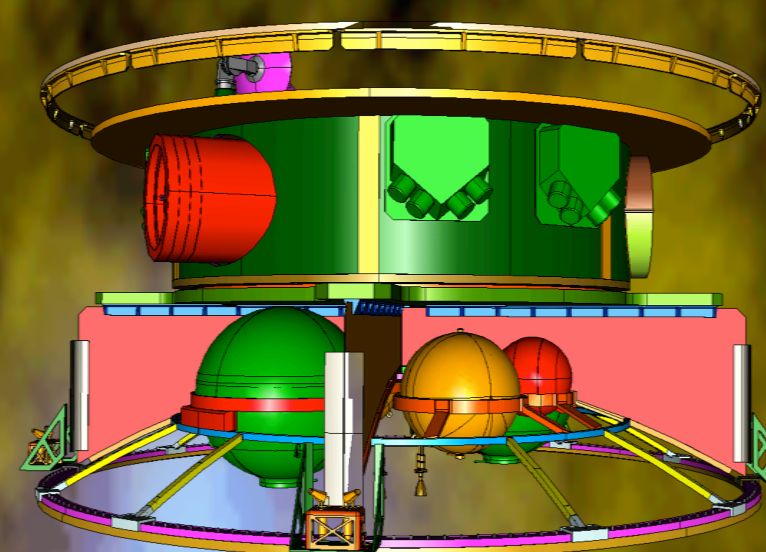
- The LISA “instrument” that detects gravitational waves is the three cooperating sciencecraft and not the “payload” on each LISA sciencecraft
- Mission Design, through the selection of orbits and operational strategies, allows the instrument to meet science performance over its 5 year data acquisition lifetime
  - Orbits provide a thermally benign payload environment; minimized non-gravitational perturbations to allow for accurate micro-Newton propulsion control; passively maintaining arm lengths (without the need for orbit maintenance); and a communications distance that allows adequate link margins using standard subsystem components
  - Small data volume allows use of standard Deep Space Network (DSN) services
- LISA will observe all the sources simultaneously all the time, with scheduled interruptions only for short periods of time needed for communications and maintenance tasks
  - eliminates operational constraints, the need of a time allocation for dedicated observations, and prioritization of science objectives

Mission Segments

- The LISA Mission is comprised of the launch segment, flight segment, ground segment, and science data processing segment –
  - The **Launch Segment (LS)** includes the Launch Vehicle and the related infrastructure at the launch site
  - The **Flight Segment (FS)** consists of three sciencecraft (each comprising a Bus and Scientific Complement/Payload (P/L)), and three Propulsion Modules (P/M); the combination of the sciencecraft and a P/M is referred to as the Spacecraft (S/C); the combination of 3 S/C constitutes the Stack; the three sciencecraft operating together on-orbit defines the Constellation.
  - The **Ground Segment (GS)** comprises the infrastructure required for ground command, control, communications, operations and data archiving and distribution, including GSE necessary for development and maintenance; it also includes the DSN services
  - The **Science Data Processing Segment (SDPS)** comprises the ESA and NASA facilities needed for analysis of science data

Sciencecraft





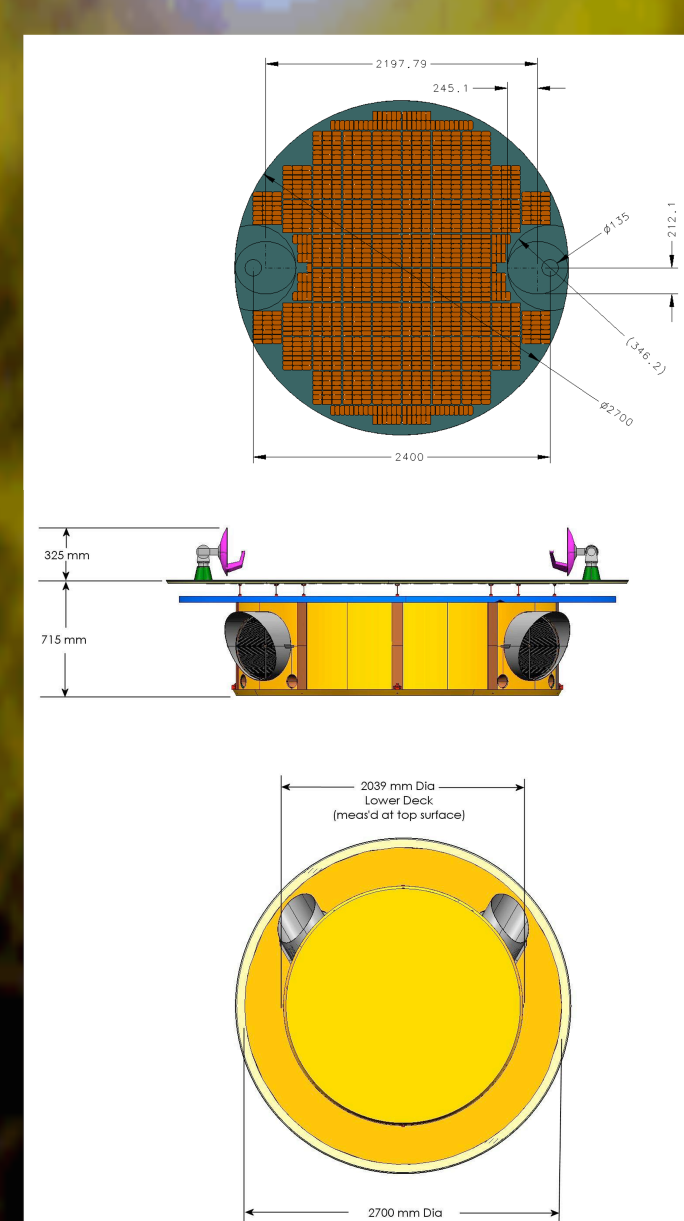
Payload

- The LISA Payload implements the primary measurement of changing proof mass separation
- The constellation of three sciencecraft form an equilateral triangle with 5 million km sides. Each sciencecraft contains a pair of “free-falling” proof masses that define the ends of the measured arms.
- The system determines the range between proof masses on different sciencecraft using interferometric laser ranging in a transponder configuration.
- The two primary components of the payload are the –
  - Disturbance Reduction System (DRS)
    - 2 kg proof mass housed in a housing for electrostatic actuation and sensing
    - Interferometric metrology system measuring from proof mass to optical bench
    - Active charge control to minimize spurious electrical forces
    - Drag-free stationkeeping with micro-Newton thrusters for reducing unwanted disturbances
  - Interferometry Measurement System (IMS)
    - 1 Watt laser pre-stabilized to a reference cavity and locked to average armlength
    - 40 cm diameter f/1.5 telescope
    - High stability Zerodur optical bench
    - Multi-channel phasemeter – digitizes interference fringes with micro-cycle accuracy

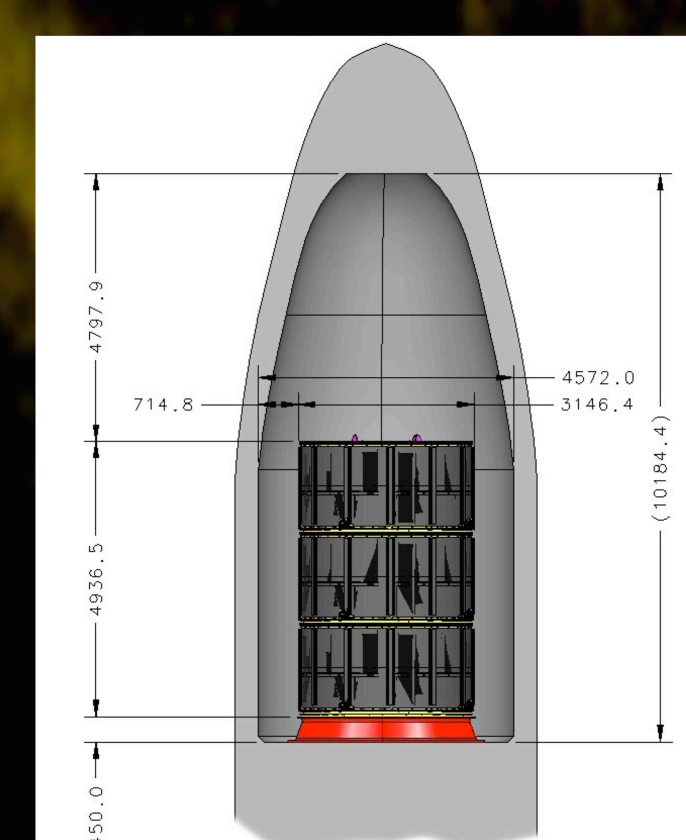
Propulsion Module

- The P/M utilizes a bi-propellant propulsion system to provide the delta-v required to transfer the S/C from its separation from the launch vehicle upper stage to its operational heliocentric orbit
- The P/M also provides: support to the sciencecraft during ground operations and the primary load path for the S/C during launch
- The P/M design includes:
  - A structure that supports all of the propulsion subsystem elements, provides a stiff interface with the launcher and supports the Sciencecraft
  - Propulsion subsystem elements (propellant storage, regulation & distribution and thrusters)
  - Electrical interface between the propulsion subsystem to the Sciencecraft . The Sciencecraft will provide all power, thermal control and command functions to the P/M.
  - A thermal subsystem (e.g. including but not limited to: MLI, thermal spacers, heaters, paint, thermistors/thermostats etc) to maintain the P/M temperature within acceptable limits

Spacecraft



Stack



Bus

- The Bus configuration is designed to ensure the requirements of the P/L, essentially very low mechanical, thermal, magnetic and gravitational disturbances in the mHz range, are met
- Design is low-risk and requires only one new technology
  - The structure consists of a cylindrical center section with a top and bottom panel for PL and avionics mounting, primary launch loads are carried by the P/M allowing the Bus structure to be constructed from aluminum honeycomb composites resulting in a relatively light structure
  - Flexible/deployable appendages on the spacecraft are minimized to avoid mechanical disturbances in the science measurement bandwidth, and to eliminate failure mechanisms
  - All proof masses are separated as much as possible from other equipment to simplify self-gravity compensation
  - Thermal stability is achieved through passive design, mandating a payload thermal environment well decoupled from both solar radiation and the Bus structure itself
  - All Bus avionics (C&DH, Communications, and EPS) are of standard heritage design
  - High Gain Antennas are the only actively pointed components
  - Solar Array are non-deployable, and “backwired” to minimize magnetic field effects
  - Micro-Newton thrusters (new technology) are employed to provide the required fine control for the ACS system